Prince George Forest Region

Forest Resources & Practices Team

March 1999
Note #PG-16

FOREST RESEARCH NOTE

Soil Rehabilitation in the Prince George Forest Region: *A review of two decades of research*

Paul Sanborn[1], Marty Kranabetter[2], and Chuck Bulmer[3]
Ministry of Forests Research Program

Simple treatments can restore productivity to landings on many common soil types.

Introduction

Under the *Forest Practices Code*, soil rehabilitation is required in two situations: (1) anticipated — where temporary access structures have been approved in a Silviculture Prescription (SP), and (2) unanticipated — where levels of soil disturbance specified in an SP have been exceeded.

Soil rehabilitation methods are also being used to return older access structures to the productive land base. Major programs of operational soil rehabilitation, dealing with such "backlog" sites and funded by Forest Renewal BC, are currently active in several areas of the central interior.

Whether driven by regulatory requirements or concerns for future timber supply, all soil rehabilitation activities share a common set of tools and techniques, as documented in the *Soil Rehabilitation Guidebook* (Ministry of Forests, 1997.) The *Guidebook* builds on a growing body of field research and practical experience, much of it based on work begun in the Prince George Forest Region as early as 1980 by soil scientists Bill Carr, Angus McLeod, and Marty Osberg. A more extensive review and problem analysis from a province-wide perspective was provided by Bulmer (1998.)

This *Note* provides a chronological summary of the key features and major findings of these field studies. For brevity and ease of comparison, additional details of the rehabilitation treatments are presented in a tabular summary (Table 1.)

Figure 1. Lodgepole pine on rehabilitated landings at 29000 Road Site, Mackenzie Forest District, May 1997.

Recognizing the Problems

Early observations attributed poor tree growth performance on landings to high soil bulk densities and reduced nutrient availability.

An initial study by Carr (1987b) examined the physical and chemical properties of both winter and summer landings constructed on sandy soils in the Mossvale area, 40 km NW of Prince George. Comparisons with adjacent undisturbed soils showed the landings to have significantly higher bulk densities and lower concentrations of major nutrients, as a result of compaction by heavy equipment and/or exposure of naturally dense subsoils, and displacement of more fertile surface soil horizons. These soil changes were associated with markedly reduced lodgepole pine height growth — effects which were becoming more pronounced 11 years after logging. In a similar study north of Fort St. James, Carr (1988) also found an increasing divergence in height between pine seedlings planted on landings and natural regeneration in the surrounding cutblock. These results led Carr to recommend that rehabilitation measures had to include both decompaction treatments and improvement of soil fertility.

Carr noted that although existing rehabilitation guidelines generally called for decompaction to 30 cm and topsoil replacement, there was little basis for prescribing a standard tillage depth. Evaluation of early operational rehabilitation efforts indicated that the tillage equipment available in the early 1980s, such as rock rippers, had limited success in producing lasting reductions of soil bulk

1 *Prince George Forest Region*
2 *Prince Rupert Forest Region*
3 *Kalamalka Research Station*

density. In addition, topsoil recovery was made very difficult by landing construction methods that incorporated other debris, such as stumps, into topsoil piles.

Early Field Trials

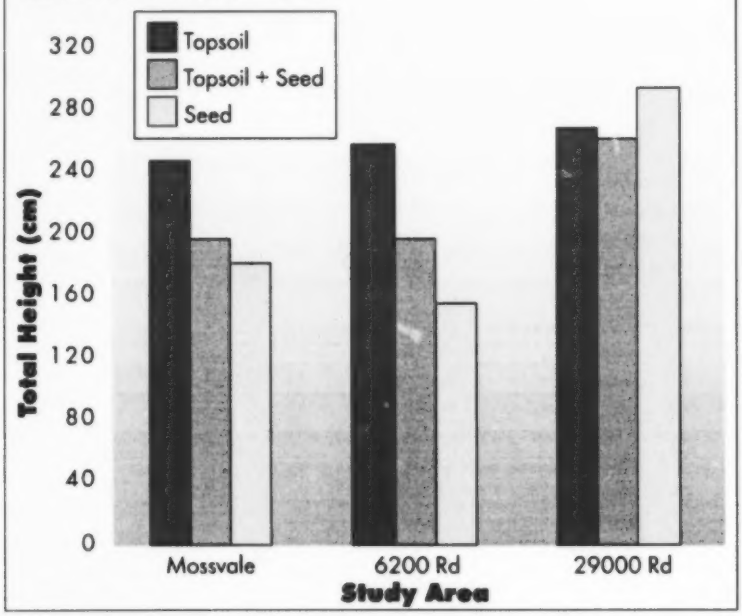
Seeding with fallow crops (grasses and legumes) and fertilization can improve nutrient availability.

In a field trial established in 1980, 30 km south of Vanderhoof, Carr (1987a) examined the effects of legume seeding and fertilization on coarse-textured landings which had been ripped to a depth of 50 cm (Table 1.) Two years after seeding in 1981, nitrogen pools in the soil and vegetation had increased by approximately 156 kg/ha/yr, over and above the N added as fertilizer. This amount of N addition, presumably by symbiotic fixation, was comparable to rates observed in agricultural legume stands. Soil concentrations of available potassium (K) also increased. However, this short-term study did not assess the persistence of agronomic legumes, or improvements to the growth and nutritional status of planted lodgepole pine seedlings.

In this initial study, the focus was on enhancing soil nutrient capital as a prerequisite for restoring site productivity. Only above ground production by the legumes was assessed; no consideration was given to below ground legume biomass production, restoration of soil organic matter, or improvement of soil structure.

Almost all subsequent research trials in this region, as well as operational soil rehabilitation treatments, have included seeding with mixtures of agronomic legumes similar to those used by Carr (Table 1.) There has been no systematic local experimentation with various seed mixtures or seeding rates, nor have experiments directly addressed factors which might influence the success of legume establishment, such as season of seeding or seedbed condition.

Figure 2. Mean Lodgepole Pine Height After Eight Growing Seasons



Expanding the Network of Research Sites in the mid-1980s

Introduction of the winged subsoiler in the mid-1980s enabled more effective tillage treatments.

The 3 large trials established in 1987 in the Prince George and Mackenzie Forest District were the first research installations in the interior to use the winged subsoiler in decompaction treatments (Table 1) (Kranabetter and Osberg, 1995.) Tillage results appeared to be much more effective than with earlier equipment types such as rock rippers. As measured by the percentage of shattering of the compacted soils, the best results were obtained for soils with coarse textures and a high coarse fragment content. Less effective shattering occurred with medium textures (silt loam, loam), especially when the subsoiling occurred under wet conditions.

Since the mid-1980s, improvements in machinery and our knowledge of appropriate soil moisture conditions for tillage have led to more effective and consistent decompaction of landings constructed on medium-textured soils. Some questions remained as to whether or not these tilled soils might return to their pre-treatment bulk density over time. Kranabetter (1998), however, found no evidence of soil resettling on medium-textured landings two years after subsoiling, demonstrating that when this treatment was used correctly, it was effective in alleviating compaction, even in poorly structured subsoils.

•

Topsoil recovery is more critical for rehabilitation success on medium-textured soils than for coarse-textured soils, but careful handling is important.*

In the BC central interior, Luvisols are the most widespread forest soil on medium-textured parent materials (Valentine and Dawson, 1981.) In such soils, most tree roots are confined to the forest floor and the somewhat coarser surface mineral horizons (silt loam or loam) which overlie denser B horizons with a higher clay content. Based on these observations, this generation of rehabilitation trials included recovery and spreading of topsoil as a key treatment — the objective being to restore the portion of the soil profile most significant for root growth.

The topsoil recovered in these trials varied considerably in quality, depending on the care taken during

* "Topsoil" has been operationally defined in the *Soil Rehabilitation Guidebook* as "the uppermost soil layer, usually including the top 20-25 cm of mineral soil, where the bulk of the rooting zone is located."

Table 1. Summary of treatments used in landing rehabilitation research, Prince George Forest Region (1980-1996.)

Site (Reference/ Researcher)	Soil Texture Parent Material	Tillage Methods*	Fertilization*	Seeding*	Topsoil and/or Amendments	Tree Species
Vanderhoof Forest District (Carr,1987a)	Sandy loam — Sand, glaciofluvial	Ripped to 50 cm with 3-toothed plow	300 kg/ha 19-19-19	40 kg/ha (mix of alfalfa, trefoil, & subterranean, white & alsike clover	Nil	Lodgepole Pine
Mossvale, Prince George Forest District (Kranabetter & Osberg, 1995)	Loam, morainal	Ripped to 50 cm with winged subsoiler	200 kg/ha 19-19-19	(same as above)	3 treatments: (1) topsoil respreading (10-20 cm), (2) seeding only (3) topsoil + seeding	Lodgepole Pine (inter-planted with Sitka alder)
6200 Road, Mackenzie Forest District (Kranabetter & Osberg, 1995)	Loam, morainal	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)
29000 Road, Mackenzie Forest District (Kranabetter & Osberg, 1995)	Sandy loam, glaciofluvial	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)
Mackenzie Forest District (Kranabetter, 1990)	Loamy sand, glaciofluvial	Tilled with winged subsoiler	2 rates: (1) 2750 kg/ha 46-0-0 + 500 kg/ha 11-51-0 + 2175 kg/ha 0-0-60 (2) 2 X above rates	Nil	56.4 or 112.8 tonnes/ha pulp fibre sludge, disked into surface 10 cm	Lodgepole Pine
Vana Vana, Prince George Forest District (C. Bulmer)	Silt loam, morainal	Tilled to 50 cm with 5-tined site prep rake on hydraulic excavator (some treatments not decompacted)	225 kg N + 50 kg P_2O_5 + 50 kg K / ha	50 kg/ha (mixture of alfalfa, trefoil, & red, white, & alsike clover)	Rotted sawdust or fresh chipped slash: applied at either 76 or 152 tonnes/ha; mulched or incorporated to 20 cm depth	Lodgepole Pine
Aleza Lake, Prince George Forest District (Sanborn *et al.*, in press)	Silty clay loam — heavy clay, glaciolacustrine	3 treatments: (1) winged subsoiler to 60 cm, (2) 5-tined site prep rake on hydraulic excavator (3) excavator (as in 2) used to incorporate wood chips	400 kg/ha 18-18-18 (+ 2000 kg/ha 35-0-0-12 in treatment 3)	(same as above)	140 tonnes/ha chipped waste wood, incorporated to 30-35 cm	Spruce, birch, or 50:50 Sx-Fp mixture

* When not specified otherwise, the techniques indicated in these categories were applied to all plots in a given study.

initial landing construction. For example, mixing of woody debris with topsoil during construction, followed by burning, resulted in loss of organic matter and N. The presence of excessive amounts of woody debris in the topsoil made subsequent recovery and spreading difficult, resulting in creation of loose, unplantable areas.

Lodgepole pine growth after 8 years indicated the benefits of topsoil replacement on medium-textured soils (Mossvale and 6200 Road sites), unlike on the coarse-textured soils where growth on the rehabilitated landings was satisfactory, regardless of treatment (29000 Road site) (Figures 1 & 2.) For an undemanding species such as lodgepole pine, recovered topsoil may also provide a sufficient nutrient supply, making fertilization unnecessary.

•

Many agronomic legumes may not persist long enough to provide adequate vegetation cover on rehabilitated areas.

After 6 years, the most persistent legume species at the Mossvale sites in Prince George District was birdsfoot trefoil, despite comprising only 10% of the initial seed mix. This species established slowly, but gradually increased its coverage, and was observed to have spread onto untreated, compacted soils. Minor amounts of alfalfa had also persisted, but the common agronomic clovers (red, alsike, white) had largely disappeared. Testing is currently underway to determine if native legumes might be better adapted to local conditions than agronomic species.[5]

•

Nitrogen-fixing shrubs, such as Sitka alder, may be useful in revegetation, but plantings in the mid-1980s performed poorly.

N-fixing shrubs may be a useful component of rehabilitation treatments. Although Sitka alder is widely distributed in Prince George Region, and frequently colonizes disturbed, infertile soils, the alder seedlings planted in these trials performed poorly. At the time, only a coastal seed provenance was available, which likely accounted for apparent repeated winter dieback. Later demonstration plantings at the Aleza Lake Research Forest near Prince George used a more locally-derived seed source, and winter survival was much better.

Using Organic Amendments

Incorporation of organic matter can potentially increase soil water retention, maintain low bulk densities after tillage, and stimulate soil biological activity.

Because urban populations in the northern interior are small, the availability of high quality organic wastes such as domestic sewage sludges is limited. Therefore, rehabilitation trials involving organic soil amendments have applied the much more abundant waste materials from the forest industry itself, such as pulp mill sludge, sawdust, and chipped logging residues.

•

Pulp mill sludge decomposes very rapidly in soils, and may not promote lasting changes to soil properties, especially in coarse-textured materials.

In a trial established in 1987 near Mackenzie (Kranabetter, 1990), locally-produced pulp mill sludge was applied at 2 rates to coarse-textured landings, which were subsequently planted to lodgepole pine in 1988. High rates of nitrogen fertilizer were added to balance the very high carbon content of the sludge (carbon in the sludge occurs mostly in the form of cellulose, which is easily decomposed in soil.) After only 7 years, very little of the sludge remained, and there was no dramatic difference in pine growth between tilled plots which had received the sludge and those which had not.

These coarse-textured soils naturally retain less organic matter, because their large pores provide a good environment for soil organisms, promoting rapid decomposition; also, the relatively small particle surface areas (compared to finer-textured soils) provide less opportunity to protect organic matter from microbes by physical adsorption to mineral grain surfaces. More lasting effects on soil properties from organic amendments are likely when soil textures are finer, and the soil amendments contain a higher proportion of biologically-resistant substances, such as lignins.

•

Woody amendment characteristics, along with the rate and method of application, affect early growth of tree seedlings.

In 1994, C. Bulmer, then of the Canadian Forest Service, established a landing rehabilitation trial to compare the effects of wood wastes (sawdust, chipped logging slash) on soil properties and lodgepole pine seedling growth. Soils at the study site near Vama Vama Creek, 44 km east of Prince George, are formed on medium-textured (silt loam) morainal deposits. Tillage was conducted with an hydraulic excavator, and the 10 treatments included both mulching and incorporation of the wastes.

Woody amendments applied as mulches reduced soil temperatures throughout the growing season, and the effect was more noticeable for a 10 cm layer of wood chips than for a 5 cm layer. At this latitude, mulches should be kept thin (5 cm), and are best used on warm, dry sites. The warmest soil temperatures, and the best tree growth after three years, were obtained for plots that were tilled only, *without* the addition of an organic amendment. Continued monitoring of the site is planned

[5] Selection of northern BC native legumes and grasses for erosion control and soil rehabilitation purposes is currently being conducted by Symbios Research and Restoration of Smithers (FRBC Project SB96031-RE.) Contact Dr. Phil Burton (Phone: 250-847-0278; E-mail: symbios@mail.bulkley.net) for current project status.

to evaluate potential future benefits of the added organic matter. Trees growing on plots where old sawdust was applied as a soil amendment were consistently larger than those growing where fresh wood chips were used, but the reasons for this effect are still to be determined.

For landings constructed on coarse- and medium-textured soils, the evidence thus far indicates that decompaction, and decompaction plus topsoil recovery, respectively, appear to be sufficient to restore productivity. In some cases, use of forest industry or domestic organic wastes as soil amendments could be viewed more as an option for waste recycling, rather than as an essential element of rehabilitation treatments. The expense of using organic amendments would need to be weighed against the costs or environmental effects of other methods of waste disposal, such as burning or landfilling. When the objective is waste management, application rates should not be excessive — use the amounts of carbon typically found in mature forest floors as an approximate upper limit (*e.g.*, 50-100 tonnes/hectare.)

Working with Fine-textured Soils: New Trials at the Aleza Lake Research Forest

Fine-textured soils are inherently more difficult to restore to satisfactory productivity.

The rehabilitation trials of the 1980s involved medium- and coarse-textured soils, but sites with clay loam or finer soil textures occupy a significant proportion of the land base in the southern part of the region. These soils have naturally shallow rooting zones overlying dense, clay-rich subsoils that drain slowly and are difficult for roots to penetrate. When exposed by landing construction, these subsoil materials are very difficult to rehabilitate, because they remain wet during much of the growing season, making tillage difficult.

To address these challenges, and building on experience gained from earlier trials, P. Sanborn, C. Bulmer, and D. Coopersmith established a rehabilitation research and demonstration program at the Aleza Lake Research Forest, 60 km east of Prince George in 1995. This trial seeks to compare the long-term effectiveness of deep subsoiling with two methods designed to restore a shallower surface layer approximating the depth of the natural rooting zone.

•

Hydraulic excavators and the winged subsoiler each have distinctive advantages in soil rehabilitation treatments.

The 3 main treatments allowed comparison of two methods of tillage: a winged subsoiler and a hydraulic excavator equipped with a site preparation rake (Lawrie *et al.*, 1996.) (Other silvicultural site preparation equipment may also be useful for rehabilitation, but the choices made for this study were based on the widespread availability and extensive previous use of these machines in forestry rehabilitation tillage.) The subsoiler was most efficient at treating large areas with a minimum of turning and where the landing or road did not contain buried logs or stumps. The excavator was well-suited to reclaiming topsoil from piles mixed with coarse woody debris, for incorporating the wood waste material used as a soil amendment, and for dealing with other associated tasks (*e.g.*, constructing water control structures. However, for simple tillage operations alone, the subsoiler was approximately 3 times more productive than the excavator.

The Aleza Lake trial is the first large-scale use of wood wastes in soil rehabilitation in the northern interior. In operational practices, chipped slash would be used, but logistical problems made this impossible, and instead waste logs were chipped with a tub grinder and incorporated with the excavator (Figure 3.) The low nutrient content of this material required large additions of fertilizer, equivalent to 600 kg of N per hectare, for a 10-15 cm layer of chips. The healthy green condition of seedlings as noted 1 year after planting in 1997 suggested that the amounts of added fertilizer have been adequate to balance this large addition of carbon-rich material.

•

Incorporation of waste wood chips maintained significantly lower bulk densities one year after tillage.

Although the wood chips, incorporated to a depth of 30-35 cm, were decomposing surprisingly fast, surface soil bulk densities were significantly lower than in the other two treatments after one year (Sanborn *et al.*, in press.) It remains to be seen whether such initial dif-

Figure 3. Incorporation of chipped waste wood with a site preparation rake mounted on a hydraulic excavator, Aleza Lake Research Forest, August 1996.

ferences in bulk density will be accompanied by lasting improvements to soil properties directly linked to tree productivity (*e.g.*, increased soil temperature and decreased root penetration resistance.)

•

Hardwoods should be considered for reforestation of rehabilitated areas.

The tree species used in this trial were hybrid white spruce and paper birch. As a pioneer hardwood species, birch has the advantage of a faster early growth rate and production of leaf litter from the year of planting, thus assisting in recovery of the forest floor. However, observations of seedling condition one year after planting suggest that the birch suffered considerable damage by rodents, particularly where seeding treatments have established a dense herbaceous cover. Use of only lower-growing legume species, such as white clover, might have reduced this problem.

Conclusions & Future Directions

Almost 20 years of research and operational experience have demonstrated that rehabilitation of severely-degraded structures such as landings is technically feasible. Acceptable growth rates for lodgepole pine can be achieved, but rehabilitation treatments need to consider:

(1) soil texture — results of simple tillage treatments are consistently best on coarse- and medium-textured soils, but effective decompaction of fine-textured soils is much harder to achieve, given the difficulty of timing field operations to coincide with optimum soil moisture conditions;

(2) careful handling of topsoil — ease of recovery and spreading is greatly increased by using appropriate equipment, such as excavators, and avoiding the incorporation of coarse woody debris; topsoil recovery appears to be particularly beneficial for rehabilitation of medium-textured soils, and is probably essential for successful treatment of fine-textured soils;

(3) use of organic amendments — consider their use, especially for treatment of finer-textured soils, and where local availability minimizes hauling costs; ensure that sufficient fertilizer (esp. N) is used to prevent nutrient imbalances after incorporation of carbon-rich materials;

(4) revegetation options — although research is still in progress, consider including a wider range of species in revegetation: hardwood trees, nitrogen-fixing shrubs, and native legumes (when commercially available.)

Future efforts should focus on ensuring that field practices reflect and build upon the lessons of past research. Continued monitoring of existing installations will be critical for assessing long-term restoration of site productivity and recovery of soil properties.

For further information contact:

Paul Sanborn, Research Soil Scientist
BC Ministry of Forests, Prince George Forest Region
1011-4th Avenue, Prince George, BC V2L 3H9
Telephone: (250) 565-6100 Fax: (250) 565-4349
email: Paul.Sanborn@gems9.gov.bc.ca

References

Bulmer, C. 1998. Forest soil rehabilitation in British Columbia: a problem analysis. *Land Management Handbook 44.* Research Branch, Ministry of Forests, Victoria. 45 p.

Carr, W.W. 1987a. Restoring productivity on degraded forest soils: two case studies. *FRDA Report 002.* Canadian Forest Service / B.C. Ministry of Forests and Lands. 21 p.

Carr, W.W. 1987b. The effect of landing construction on some forest soil properties: a case study. *FRDA Report 003.* Canadian Forest Service / B.C. Ministry of Forests and Lands. 20 p.

Carr, W.W. 1988. Nutritional and soil compaction aspects of establishing forest cover on winter landings in the Fort St. James area. *FRDA Report 047.* Canadian Forest Service / B.C. Ministry of Forests. 6 p.

Kranabetter, M. 1990. Pulp fibre waste as a soil amendment: rates of net carbon mineralization. M.Sc. thesis, U.B.C.

Kranabetter, M. 1998. Does soil resettling occur after decompaction? *Extension Note 29.* Ministry of Forests, Prince Rupert Forest Region, Smithers.

Kranabetter, M. and M. Osberg. 1995. Landing reclamation trials in the Prince George Forest Region. Unpublished Forest Sciences Report. Prince George Forest Region. 10 p.

Lawrie, D., R. K. Krag, P. Sanborn, and C. Bulmer. 1996. Reclamation of compacted fine-textured soils on the Aleza Lake Research Forest using a winged subsoiler and a hydraulic excavator. *Technical Note TN-250.* Forest Engineering Research Institute of Canada, Vancouver.

Ministry of Forests. 1997. Soil rehabilitation guidebook (Forest Practices Code of British Columbia.)

Sanborn, P., C. Bulmer, and D. Coopersmith. (in press.) Restoring productivity to landings on fine-textured soils: early results from the Aleza Lake Research Forest. *In:* Proceedings, Helping the Land Heal: Ecological Restoration in British Columbia. November, 1998. Victoria, B.C.

Valentine, K. W. G. and A. B. Dawson. 1978. The Interior Plateau. *In* K. W. G. Valentine, P. N. Sprout, T. E. Baker, and L. M. Lavkulich. (eds.) *The Soil Landscapes of British Columbia.* Agriculture Canada & B.C. Ministry of Environment. pp. 121-134.